The Lessons Learned Process: An Effective Countermeasure Against Avoidable Risk

James F. Clawson Jet Propulsion Laboratory Pasadena

David Oberhettinger Jet Propulsion Laboratory Pasadena

Key Words: Lessons Learned, Information system, Process Improvement

SUMMARY & CONCLUSIONS

The engineering and operation of extremely complex and technically advanced systems pose unknown risks, and we must accept the likelihood of design errors throughout the life cycle. Expensive mistakes and lost opportunities are less acceptable, however, when it is discovered that the enterprise already knew how to avoid them. The lessons learned process performs a major role in communicating information essential to successful system design and development— especially under a compressed project schedule. This paper identifies success factors in the design and implementation of an effective lessons learned process and summarizes current research on methods for infusing enterprise-wide use of the lessons.

1. INTRODUCTION

The potential for errors in engineering judgment arguably presents the highest level of risk when applied to interplanetary spaceflight, with the very limited opportunities for redesign or corrective maintenance after spacecraft deployment. The Jet Propulsion Laboratory (JPL) is the lead NASA agency for the robotic exploration of the solar system. Through robust design, JPL has succeeded in deploying reliable systems despite a high rate of technology change and exceptionally severe operating environments. However, JPL must now cope with a government mandate to develop more missions with less dollar and schedule resources. Under these constraints, the organization is heavily dependent on its experience base to identify necessary design margins and resolve latent defects. JPL has been refining its lessons learned process to optimize the collection and transfer of critical success factors applicable to current and future spaceflight projects.

2. THE FORMAL LESSONS LEARNED PROCESS

Best Practice No. 1: ***Obtain enterprise-wide commitment to a formal lessons learned process.***

A formal process for lessons learned has been established by JPL to capture and disseminate key lessons while maintaining accuracy, consistent format, and ease of use. The process has the full support of the Laboratory Director and management, and the lesson products have been used for decades by the developers and operators of spaceflight missions (i.e., the flight projects and mission control). The objective is to advance JPL missions by exposing personnel to significant events from which important "lessons" can be drawn which have applicability beyond the original event.

Meeting this objective requires the active participation of technical and administrative organizations throughout the enterprise. Personnel must be encouraged to volunteer new lesson material from their prior or ongoing project experiences, and to apply already published lessons to their areas of responsibility. Project management is encouraged to maintain a running list of potential lesson topics throughout development and mission operations, and to assist in preparation of formal lessons for submission. Early in the conceptual stage and throughout project development (and mission operations), the project team reviews the compendium of published lessons to identify and incorporate lessons deemed relevant to the planned mission. Figure 1 depicts the JPL lessons learned process. Although the results of the process may be incorporated into JPL and NASA procedures and standards, the lessons are retained and widely circulated through a NASA-wide Lessons Learned Information System (LLIS).

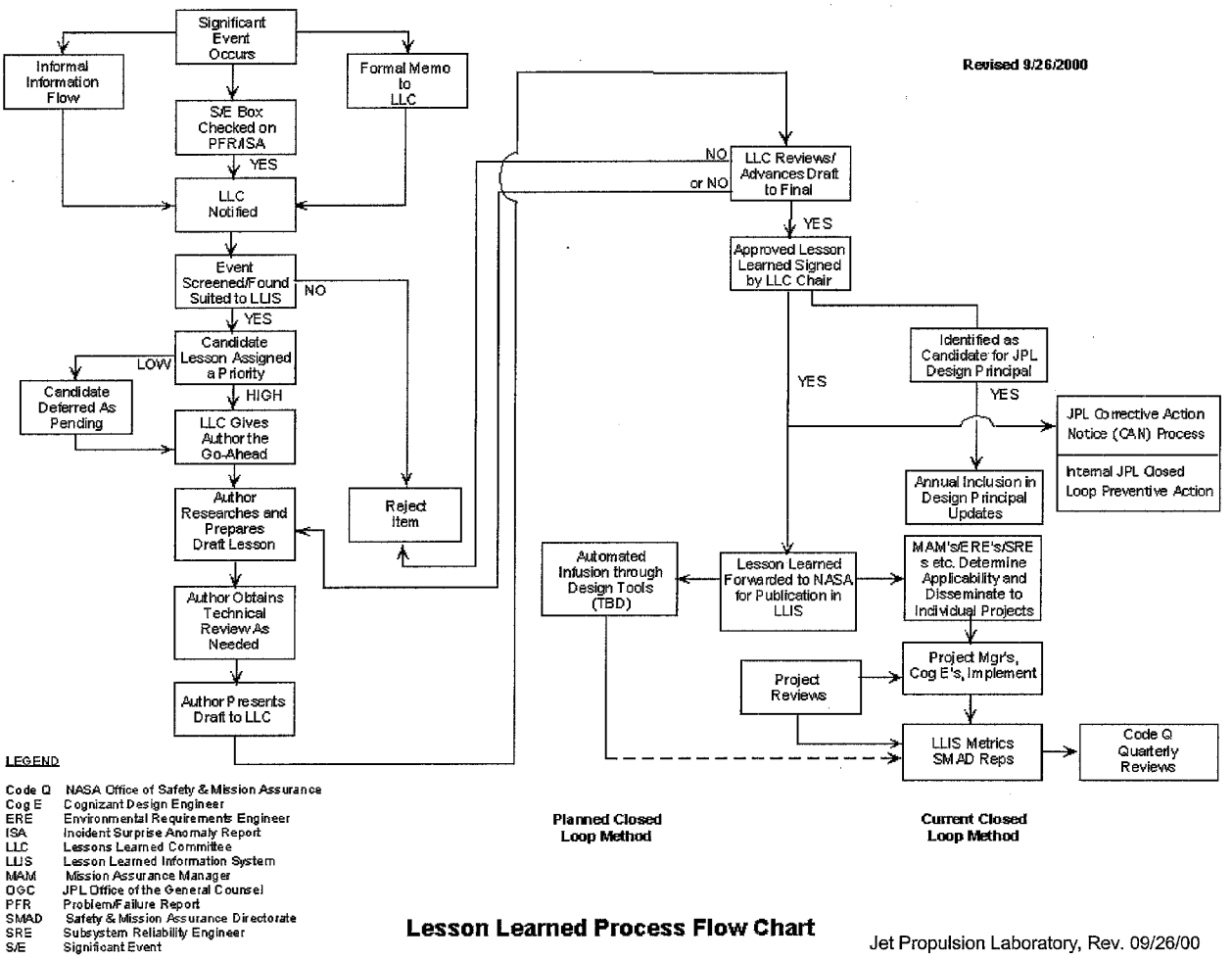

Figure 1. A Lessons Learned Process Flow

3. SOLICITATION OF CANDIDATE LESSONS

Best Practice No. 2: ***Review and prioritize candidate lessons based on their applicability to current and future projects, and periodically review published lessons for their continued relevance.***

The scope of the JPL effort is limited to documenting events arising out of-- or related to-- the design, implementation and operation of flight equipment and related support equipment and facilities. Existing corporate communication channels, such as the institutional failure reporting system, are exploited as a source of lessons learned material where possible. For example, the JPL automated problem/failure report form provides a lessons learned checkbox; when checked, a copy of the submitted report is automatically e-mailed to a lessons learned coordinator. Functional categories that have proven fruitful in generating useful lesson material include:

- Management and Planning
- Software Development
- Hardware Development
- Subsystem and Instrument Development
- System Development
- System Integration and Test
- Reliability and Quality Assurance
- Configuration Control
- Mission Operations
- Safety
- Parts, Materials, and Processes
- Institutional Systems and Facilities

Of course, non-NASA enterprises can generate a similar list reflecting the features of their product development cycle and their major areas of risk.

Once reported to a lessons learned coordinator, events are evaluated for their suitability as formal lessons based on the:

1. Significance in terms of actual or potential project impact, including effects on project success, cost, schedule, safety, public visibility, or management visibility.

2. Importance to future projects and institutional activities. Lessons may be drawn from the experiences of other enterprises if the details can be verified.

3. Lack of prior coverage of the event, or underlying issue(s), in previously approved lessons or other closed loop alert processes (e.g., GIDEP for electronic parts).

Best Practice No. 3: ***Don't limit lesson topics to "screw-ups;" also document successes that should be replicated!***

Candidate lessons are prioritized based on the above evaluation and are tracked on a status list. Formal lessons are subsequently drafted for review and approval in order of priority without regard for "first received." Events suitable for documentation as lessons are not limited to mistakes that negatively impacted missions, but should include measures that proved successful on recent projects. The total number of lessons published is not a valid measure of lesson learned program effectiveness, but rather the timely use of lessons to establish a path to mission success. To maintain quality, it is recommended that the compendium of published lessons be reviewed periodically to identify lessons that are obsolete or require updating.

4. THE KEY ROLE OF THE LESSONS LEARNED COMMITTEE

Best Practice No. 4: ***Charter a Lessons Learned Committee that represents the major technical organizations and is charged with real-time development of draft lessons.***

The key to the success of an enterprise-wide lessons learned process is a Lessons Learned Committee consisting of representatives of the major organizational elements. This committee is responsible for reviewing significant events and assuring that lessons learned are documented and distributed. The committee should meet on a regular basis to identify candidate lessons, assign action items and review their status, review and approve draft lessons, host presentations on significant incidents, discuss potentially relevant incidents within the organization or within the industry, manage lesson dissemination, and perform related activities. The committee membership fulfills an additional role as a conduit for breaking news within their respective organizations and technical disciplines. Given that stories of past mistakes may be de facto controversial, the participation of the major organizational elements may allow conflicts to be resolved within the committee structure.

The Lessons Learned Committee is not an advisory body, but a working group. For best results, the committee should meet to conduct a line-by-line review of each draft lesson, including "wordsmithing" the text, to assure the accuracy and precision of the incident description and recommendations. Experience has demonstrated the poor effectiveness of a system that hosts poorly written lessons, or lessons that lack a consistent format. Should a first-time user retrieve a lesson that is unclear or contains recommendations that are too vague to be actionable, the entire system loses credibility. This method of lesson development is neither quick nor inexpensive, but it generates a quality product.

5. THE "AUTHOR-IN-RESIDENCE" OPTION

Best Practice No. 5: ***Designate a single author to interview sources and prepare lesson drafts.***

Once a high priority topic is identified, an author designated by the Lessons Learned Committee researches the event and prepares a draft lesson. It is acceptable to have someone familiar with the incident perform this role, but it is recommended that one committee member be selected as the permanent author-in-residence who coordinates with the appropriate technical expert(s). By appointing a single author with superior writing skills, the committee:

- Avoids introducing bias stemming from an author's personal involvement in the incident,
- Assures committee control over the lesson production schedule, and
- Produces drafts of uniform quality in terms of style, format, and content— alleviating the committee's workload in reviewing draft products.

Selection of a good author as staff to the committee can greatly improve productivity and enhance the lessons learned process. Several years ago, JPL productivity tripled when this approach was implemented.

Specifications for the lesson product should be defined and consistently applied. Lessons should be written in a common format, avoiding technical jargon and undefined acronyms. Where possible, lessons should be limited to one page in length, listing references to additional information or points of contact as needed. Inclusion of diagrams and photographs is recommended to clarify the text and improve readability. The suggested lesson structure (in use by JPL) includes:

- Description of Driving Event
- Reference(s)
- Lesson(s) Learned
- Recommendation(s) (sometimes combined with Lesson(s) Learned)
- Additional Key Words (to aid in full-text searches)
- Metadata (e.g., lesson no., title, date, points of contact)

The resident author of lessons should always participate in Lessons Learned Committee meetings as an active, voting member.

Best Practice No. 6: ***The recommendations drawn from the driving event should be actionable.***

The text of the lesson should conclude with recommendations that clearly and logically proceed from the discussion of the driving event and any identified root cause(s) of the incident. Only concrete recommendations that can reasonably be implemented by the enterprise should be considered. Some suggested courses of action may be so lacking in specifics as to be meaningless. At the other extreme are those recommendations requiring expenditures or major changes in business practices that are out of proportion to the driving event, are politically infeasible, or have limited applicability. If it proves difficult to phrase useful recommendations after a short discussion, then the topic is probably not suited to documentation as a lesson learned. Similarly, if there is a strong temptation to couch a recommendation as a *requirement*, then a requirements document

may be a more credible venue than the lessons learned system.

6. RESEARCH AGENDA

Best Practice No. 7: ***Innovate to assure that the lessons learned system is a dynamic resource-- not a "data morgue."***

In response to calls for NASA to innovate at an increased pace and to better quantify levels of mission risk, it has renewed its commitment to maintaining and augmenting its enterprise knowledge base. NASA lessons learned are presently disseminated on a NASA-wide Lessons Learned Information System (LLIS) website that is full-text searchable, and can be sorted by lead NASA Center, lesson category, publication date, etc.[1] However, the LLIS represents one among a plethora of databases competing for the attention of busy project personnel. To improve the effectiveness of technical information transfer, NASA is presently researching the design of a portal that would integrate the LLIS and other resources.

In addition, JPL plans to implement a mechanism to assure that enterprise-wide problems identified through the lessons learned process gain management attention and achieve resolution. As each lesson is completed, the plan calls for the lesson approval to initiate a (possibly JPL-wide) corrective action where appropriate. Typically, this would involve a change to JPL process documentation, such as a policy, procedure, or engineering practice. The JPL Corrective Action Notice (CAN) system, which is used for formal tracking of discrepancies prompting JPL process changes, will accommodate this follow-up to publication of a lesson learned. By establishing this connection to the closed-loop corrective action process, JPL can ensure that the outputs of the lessons learned process trigger appropriate action.

7. CONCLUSION

The product of the lessons learned process is a key knowledge management tool-- a searchable collection of discrete lessons judged applicable to current and future NASA missions. Prior to implementation of the process described in this paper, information on critical success factors was communicated informally on a hit-or-miss basis. Although aerospace and other industries may assume the high level of risk associated with novel technologies and missions, they cannot afford failures to learn the lessons of their own history. In many cases, lessons from previous experience can prevent major missteps if applied before errors in engineering judgment are compounded. The efficient identification, documentation, dissemination, and use of lessons learned can provide an effective countermeasure against reasonably avoidable risks.

ACKNOWLEDGEMENT

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BIOGRAPHIES

James F. Clawson
Jet Propulsion Laboratory, California Institute of Technology
M/S: 122-107
4800 Oak Grove Drive
Pasadena, CA 91109-8099
E-mail: James.F.Clawson@jpl.nasa.gov

James Clawson manages the Reliability Engineering Office at the Jet Propulsion Laboratory (JPL) in Pasadena, California. He also chairs the JPL Lessons Learned Committee. His lessons learned experience extends from his involvement with recovery from the Apollo 13 near disaster, through the first 21 Space Shuttle missions, to his service as Mission Assurance Manager for the Mars Pathfinder mission that explored the Martian surface.

David Oberhettinger
Logicon, Inc., a Northrop Grumman company
2550 Honolulu Avenue, Suite 201
Montrose, CA 91020 USA
E-mail: davido@ieee.org

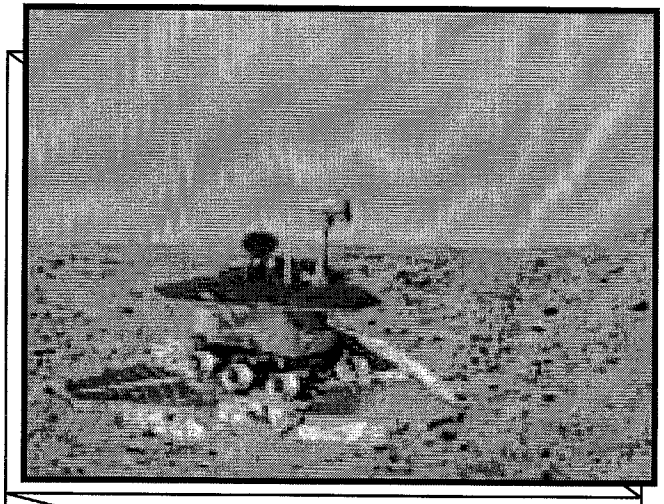
David Oberhettinger manages the Spacecraft Engineering Technology Department of Logicon, Inc. and is a member of the Reliability Technology Group at the Jet Propulsion Laboratory (JPL) in Pasadena, California. His present technical duties include participation on the JPL Lessons Learned Committee and assistance with microspacecraft reliability research. He also serves as a vice-chair on the RAMS2001 Management Committee.

[1] Access is presently limited to NASA employees and approved NASA contractors.

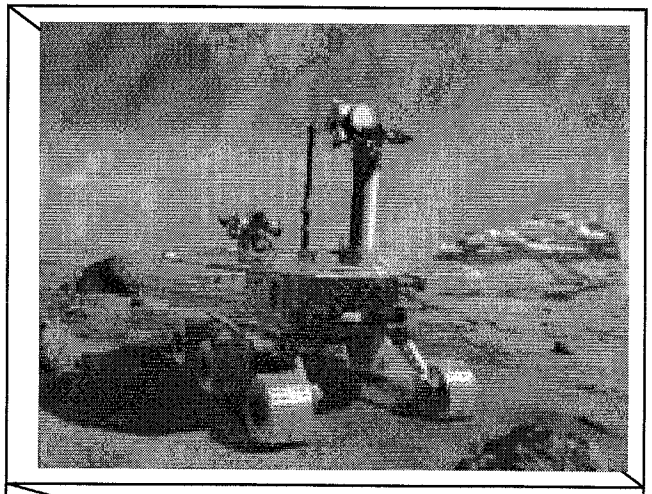
The Lessons Learned Process

"An Effective Countermeasure Against Avoidable Risk"

James F. Clawson
Manager, Reliability Engineering Office
Jet Propulsion Laboratory



Mars Mobile Lander on Air Bags
(Mars03 Program)



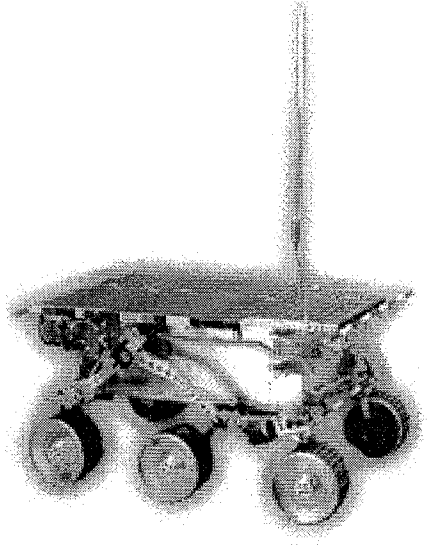
Mars Mobile Lander Deployed (Mars03 Program)

INTRODUCTION

- **JPL Environment**
  - High Rate of Technology Change and Exceptionally Severe Operating Environments
  - Limited Opportunities for Repair or Rework of Spacecraft during Interplanetary Exploration
  - Government Mandate to Develop More Missions With Fewer Resources
- **Dependence on the Institutional Experience Base to Avoid Mission Failure or Expensive Redesign**
- **Lessons Learned System**
  - Communicate Information Viewed As Essential to Successful System Design, Development & Operations

FORMAL LESSONS LEARNED PROCESS

- Objective: Capture and Disseminate Critical Success Factors Applicable to Future Projects



Best Practice No. 1: *Obtain enterprise-wide commitment to a formal lessons learned process.*

- Define Your LL Process; Obtain Enterprise-Wide Commitment and Active Participation Throughout
- Accuracy, Consistent Format, and Ease of Use Are Essential; Publication Via the Web Is Optimal

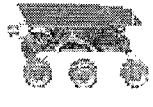
LESSON SOLICITATION & PROCESSING

- **Utilize Existing Corporate Communication Channels for Input**
  - **e.g., Failure Reporting System**
  - **Provide a List of Functional Categories to Contributors**

> **Best Practice No. 2:** ***Review and prioritize candidate lessons based on their applicability to current and future projects, and periodically review published lessons for their continued relevance.***

- **Evaluate Significant Events for Suitability As Formal Lessons, and Prioritize Candidates**

> **Best Practice No. 3:** ***Don't limit lesson topics to "screw-ups"; also document successes that should be replicated!***

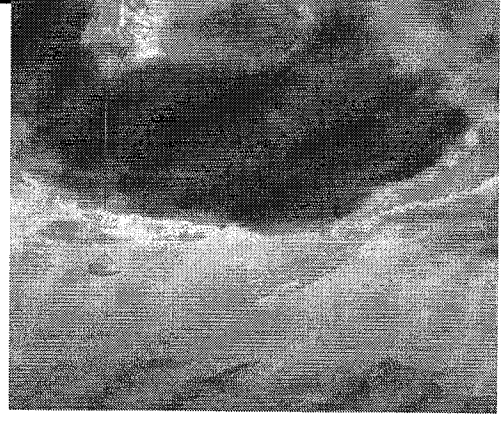


Lessons Learned Committee

- **Charter a *Lessons Learned Committee***
  - **Reviews Significant Events and Assures That Lessons Learned Are Documented and Distributed**
  - **Includes Representatives of the Major Organizations; They Roll Up Sleeves to Conduct Line-by-Line Review**

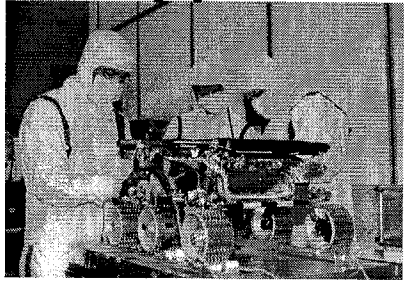
Best Practice No. 4: ***Charter a Lessons Learned Committee that represents the major technical organizations and is charged with real-time development of draft lessons.***

  - **A Credible System Requires Well-Written Lessons With a Consistent Format.**



LESSON PREPARATION

- **Use of a Dedicated Author Can Greatly Improve Productivity. JPL's Tripled When This Approach Was Implemented.**



Best Practice No. 5: ***Designate a single author to interview sources and prepare lesson drafts.***

  - **Keep it Short and Avoid Technical Jargon and Undefined Acronyms.**
  - **Organization: Description of Driving Event, References, Lesson(s) Learned, Recommendation(s), Key Words, Metadata**

Best Practice No. 6: ***The recommendations drawn from the driving event should be actionable.***

RESEARCH AGENDA

- **Need for Improved Software Tools: Lessons Learned Must Compete Against Today's Information Overload.**

> **Best Practice No. 7:** ***Innovate to assure that the lessons learned system is a dynamic resource-- not a "data morgue".***

- **Designing a Portal for Integration with Other Information Resources in a "Knowledge Mall."**
  - **"*One-Stop Shopping*": User Selects Data Repositories by Accessing Distributed Search Engine**
- **Conclusion: Lacking a Defined LL Process, Critical Success Factors Will Be Communicated Only Informally on a Hit-or-Miss Basis.**